Update on PMA/Shower Reconstruction

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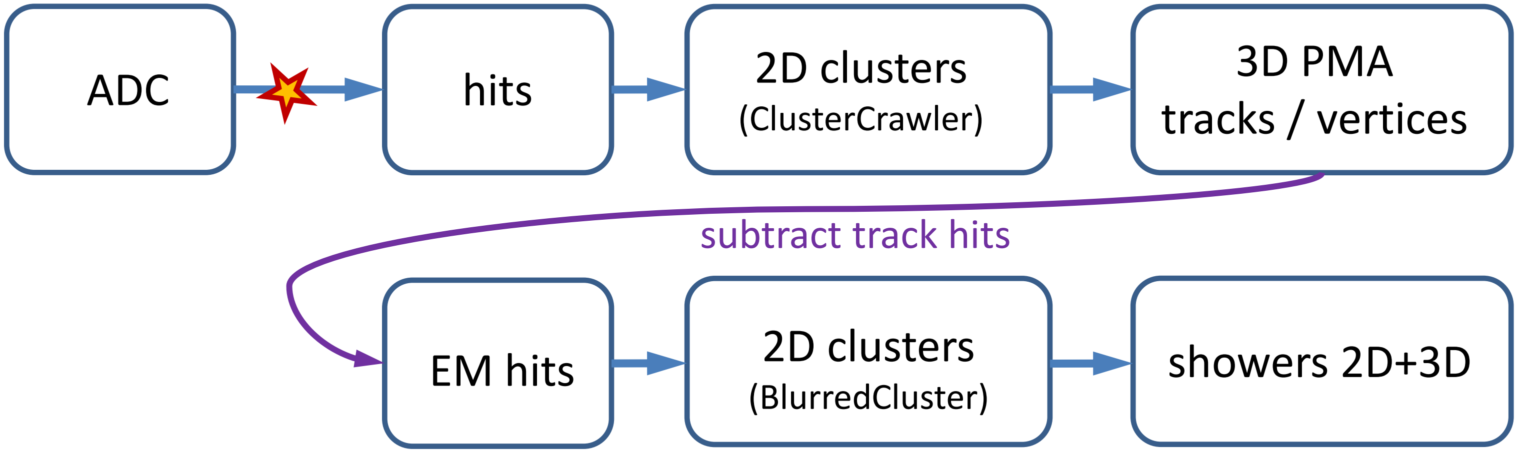
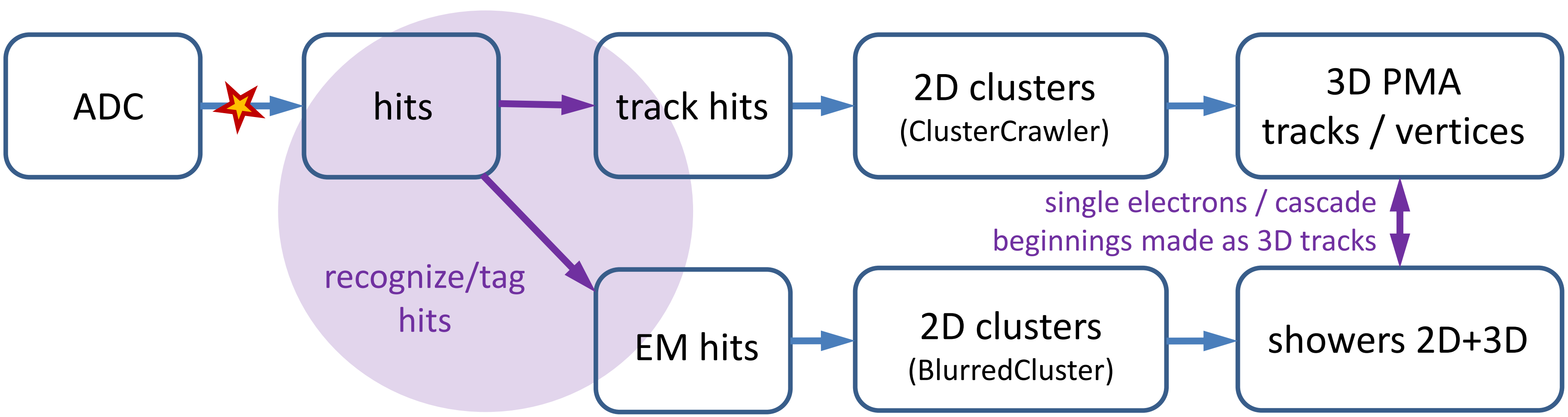
Introduction

- now we use (due to available set of tools):



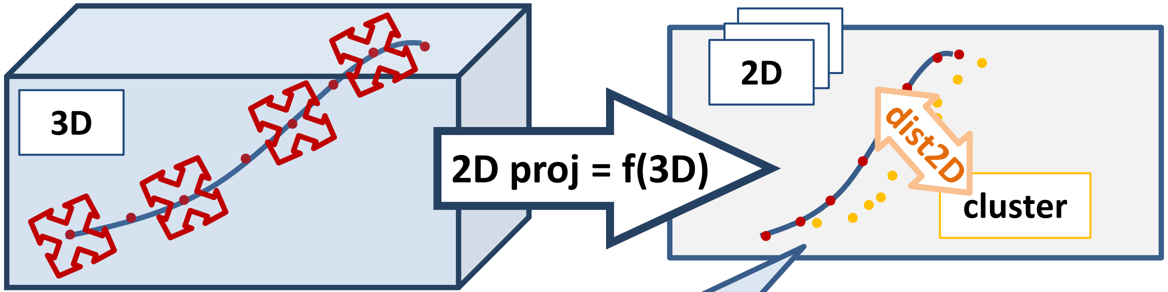
- likely more reasonable (work ongoing):



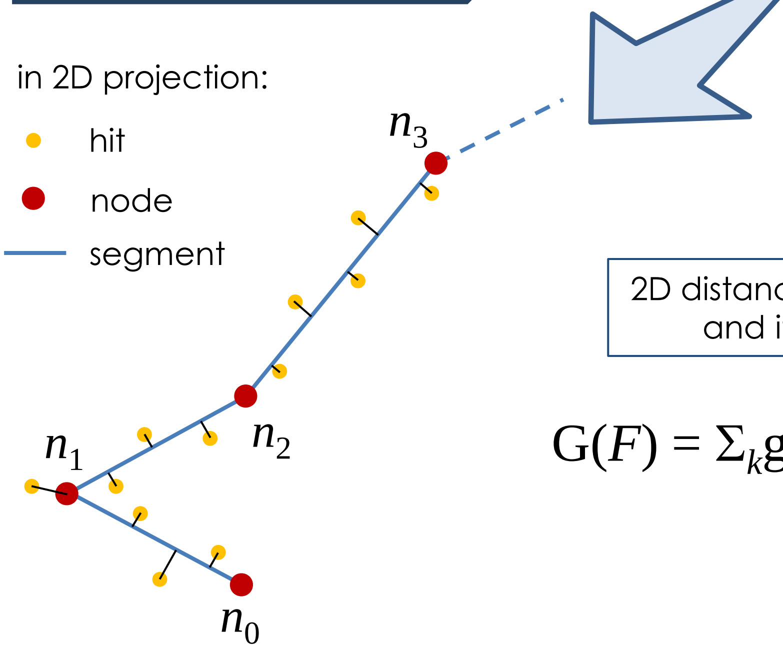
Strong data & information reduction:

- dense regions (ν primary vertex) may profit from using ADC instead of hits (work started with P.Płoński)
- PMA can also take as input ADC values instead of hits, e.g. region selected via **wire cells**

Tracking / vertexing with Projection Matching Algorithm



All details on slides, Sept. collab. meeting:
https://indico.fnal.gov/getFile.py/access?contribId=41&sessionId=11&resId=0&materialId=slides&confId=10100



Create and optimize object in 3D to match its multiple 2D projections:

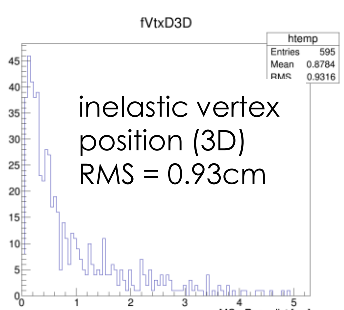
- what should be the 3D shape that results with what we see in 2D's?

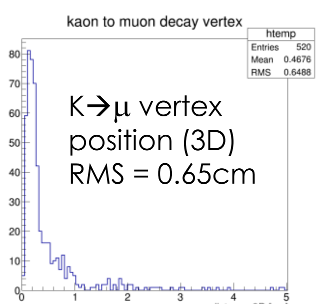
2D distance to hits assigned to node *k* and its connected segments

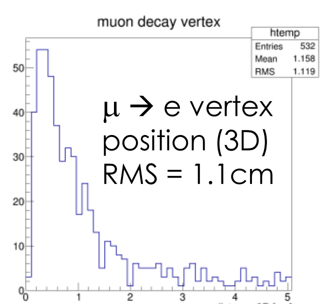
penalty on angles between segments for nodes *k*, *k*-1, *k*+1

$$G(F) = \Sigma_k g(\mathbf{n}_k) \qquad g(\mathbf{n}_k) = d(\mathbf{n}_k) + \beta_a\, c_a(\mathbf{n}_k) + \beta_v\, c_v(\mathbf{n}_k)$$

Used now to support wire-plane-parallel: ***3D distance to ref. points*** assigned to node *k* and connected segments

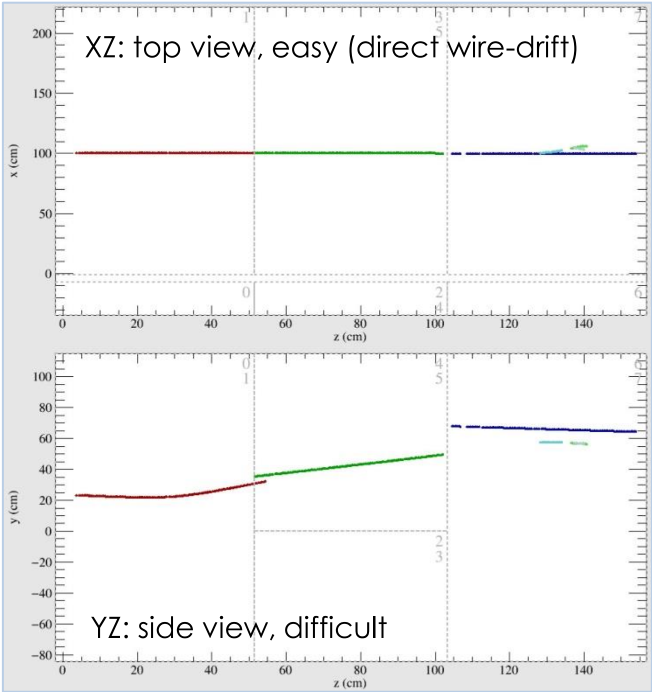




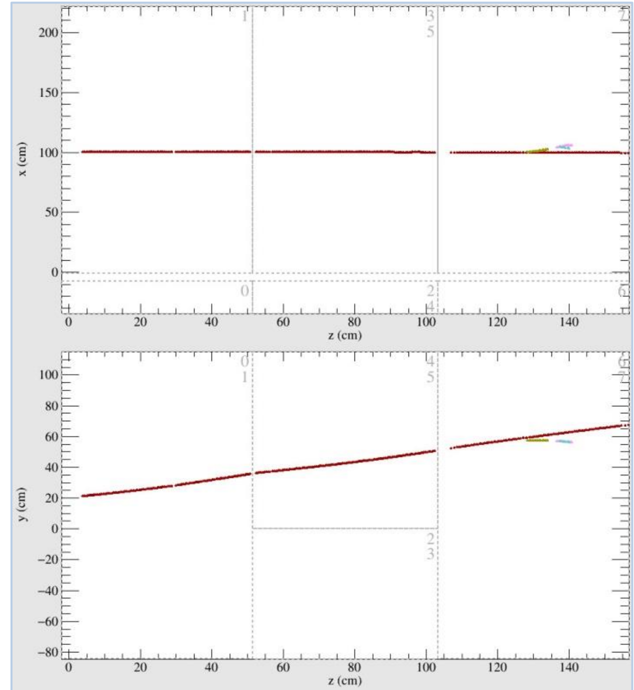


- expect slightly varying resolution for different analysis, at ~wire pitch level
- vertex finding under tests / fixes / improvments
- applied to FD neutrinos and protoDUNE beam

Wire plane parallel tracks



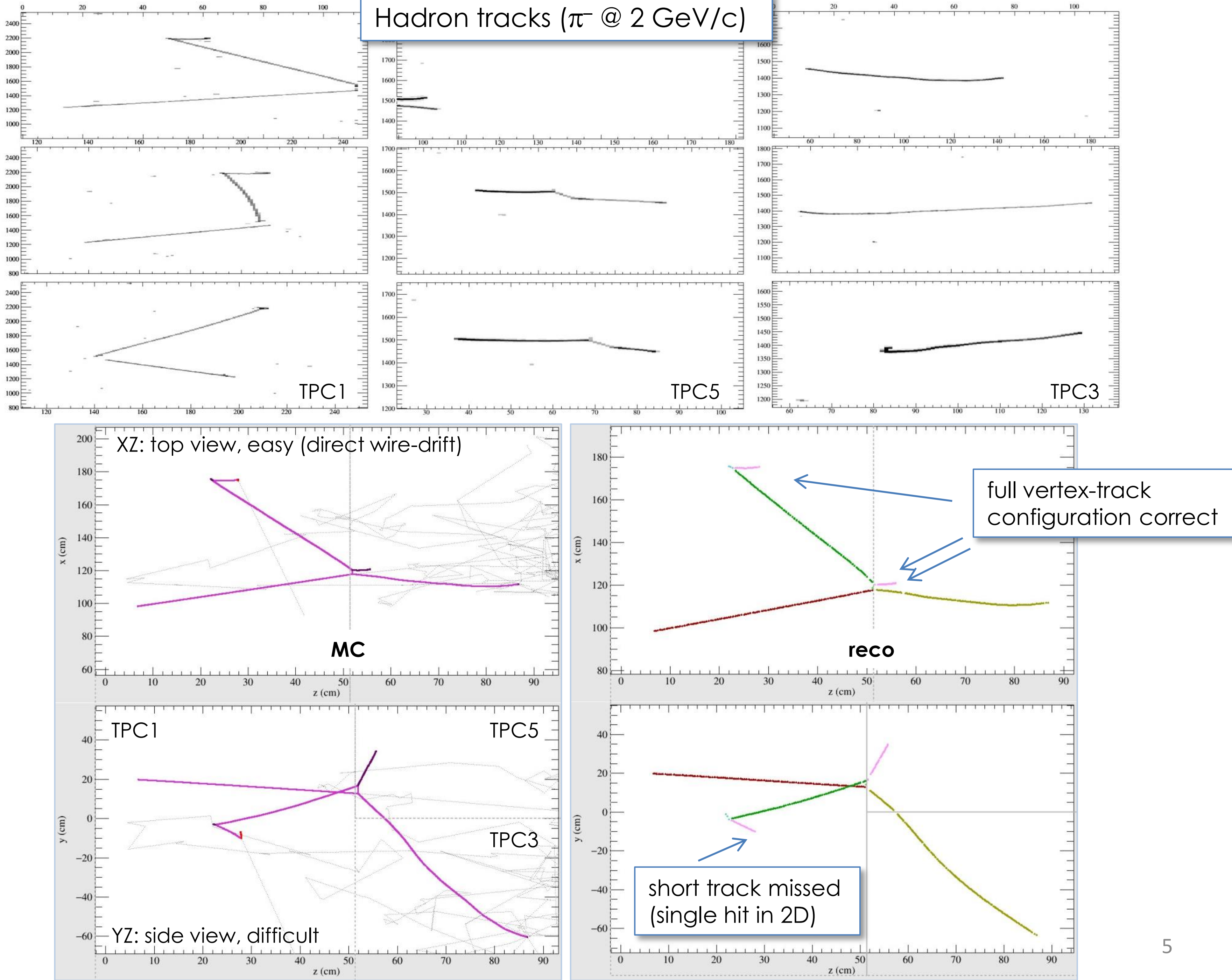
No stitching to show track parts reconstructed in each TPC.



3D ref.points & stitching applied.

- Reconstruction of tracks exactly parallel to wire plane is the most difficult.
- Optimization can include 3D reference points:
  - e.g. track **endpoints** and **entry/exit points** are easy to find (***note:*** geometry divided into not too huge TPC volumes makes the reconstruction easier);
  - optimization is only *guided*: $(d_{ref\text{-}trk} - r)^2$ used as a distance to reference point measure
- There was a drop in reco efficiency for long muons parallel to wire planes, caused by failing stitching → now should be improved.
- Isolated track reco improved → more accurate input to vertexing → more complex event topologies resolved.

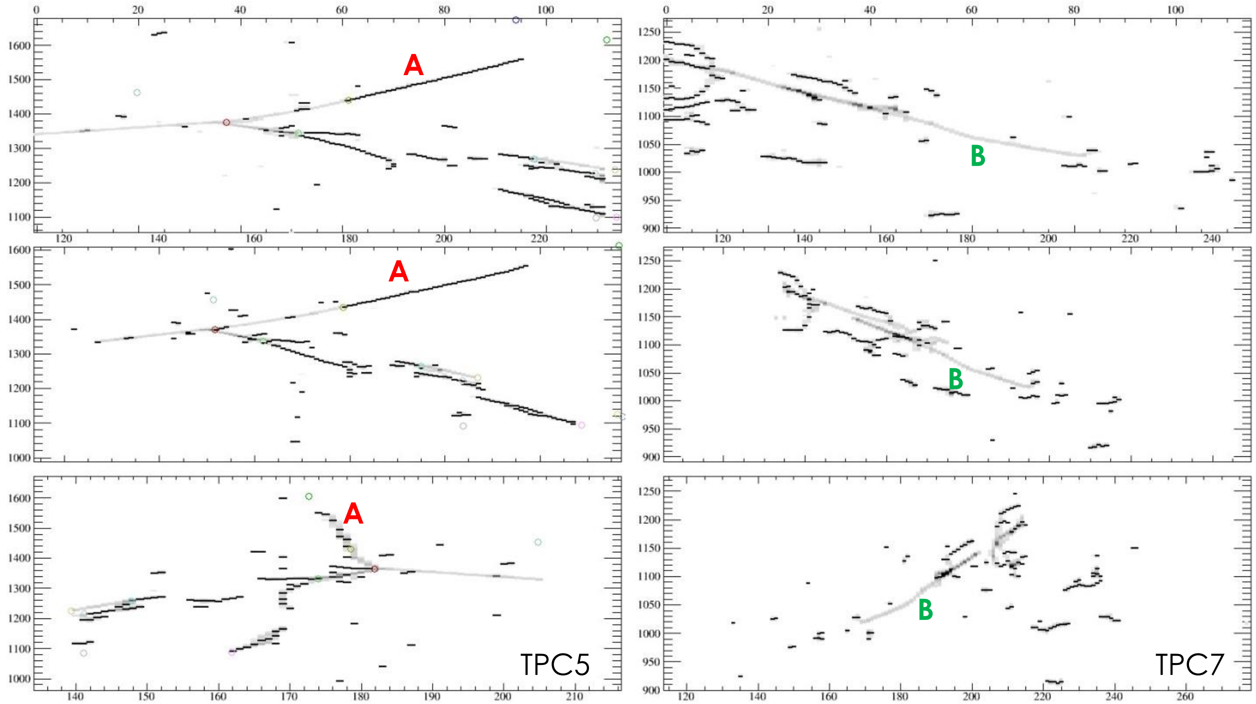
Hadron tracks (π^- @ 2 GeV/c)



Hadron tracks + EM cascades

- black hits: identified as EM parts
- done on the 3D level
- **A**: track→EM miss-ID (several improvements seems doable)
- **B**: EM→track miss-ID (not a problem)

- vertex+track topology correct (e.g. efficient for π^0 analysis)

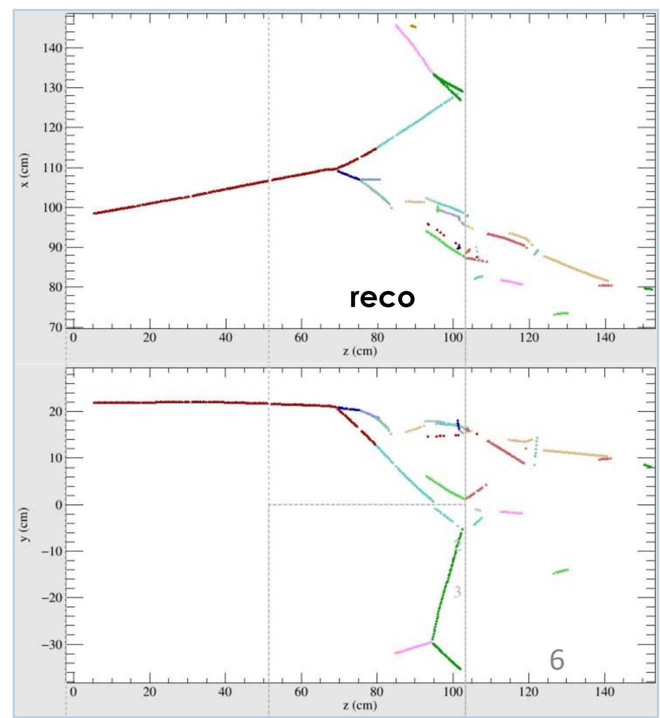


What is OK?

- Tracking and vertexing efficient, robust, resolves also complex topologies, survives crowded regions, ...

What is the issue?

- Detailed 3D tracking is not a tool to reconstruct electrons inside EM cascades (*linecluster* as well)!
- Need to select dense&chaotic hit regions in 2D processing.
- Use appropriate tools for EM hits (blurred clustering, shower reconstruction).
- Use EM identification in 3D only to complement 2D (initial cascade part made as track, isolated electrons, ...).

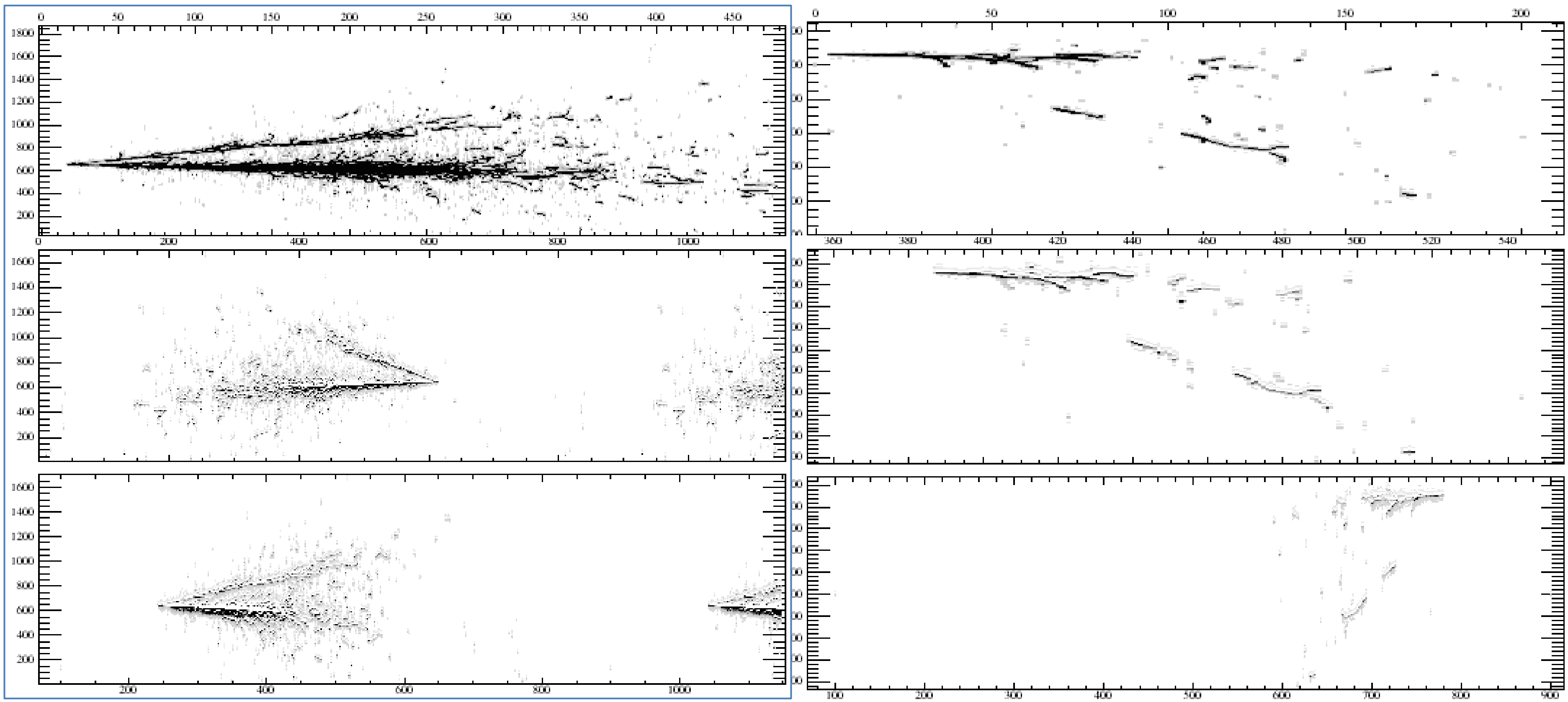


Shower reconstuction

1. First part of cascade to seperate electrons from photons via dE/dx.

2. Energy, which requires efficient shower fragments collection/seperation.

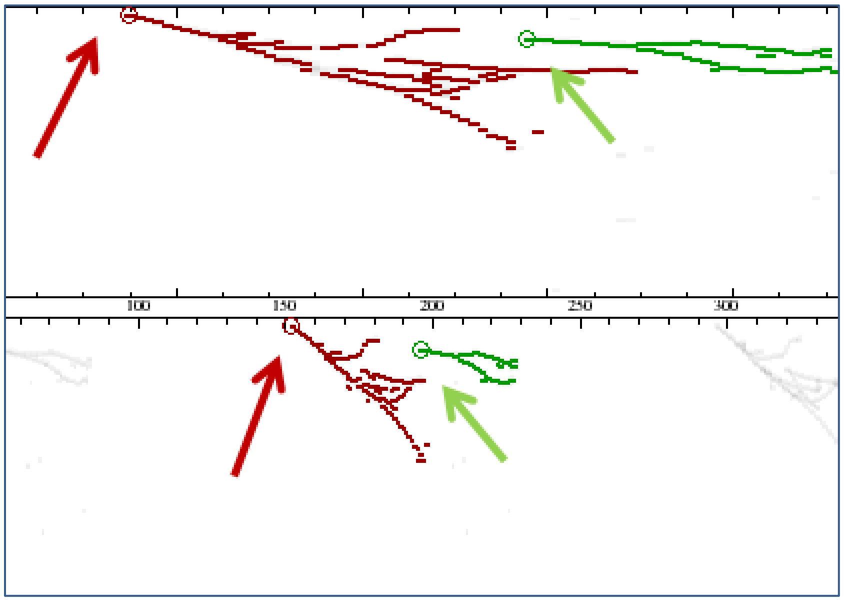
3. Profiles of cascade and its direction.

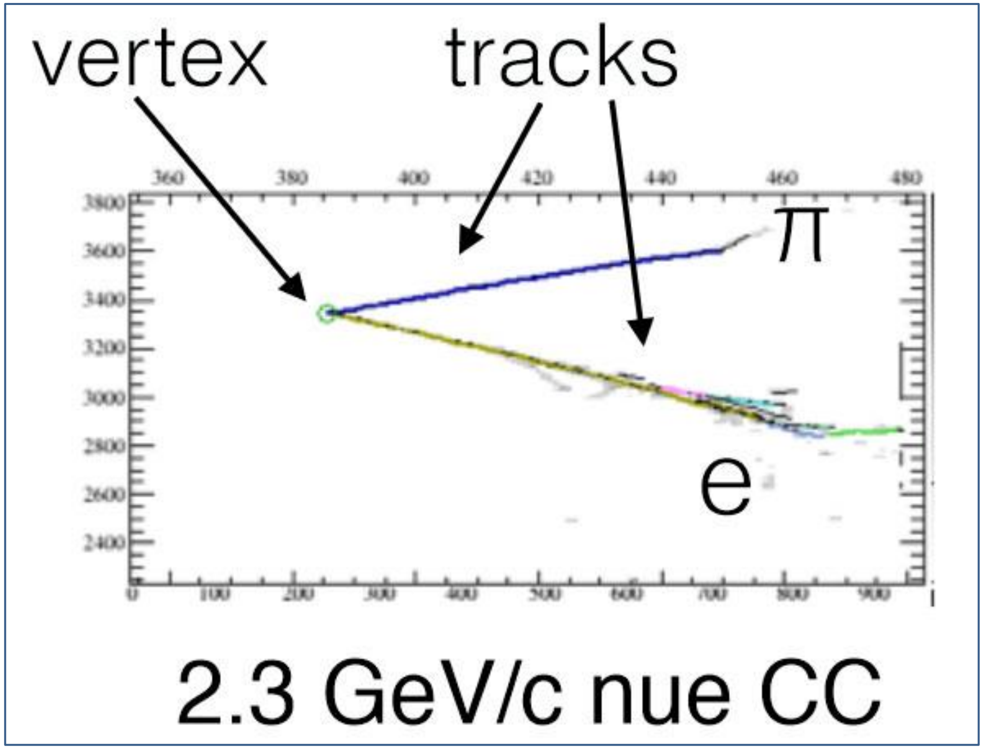


First part of cascade

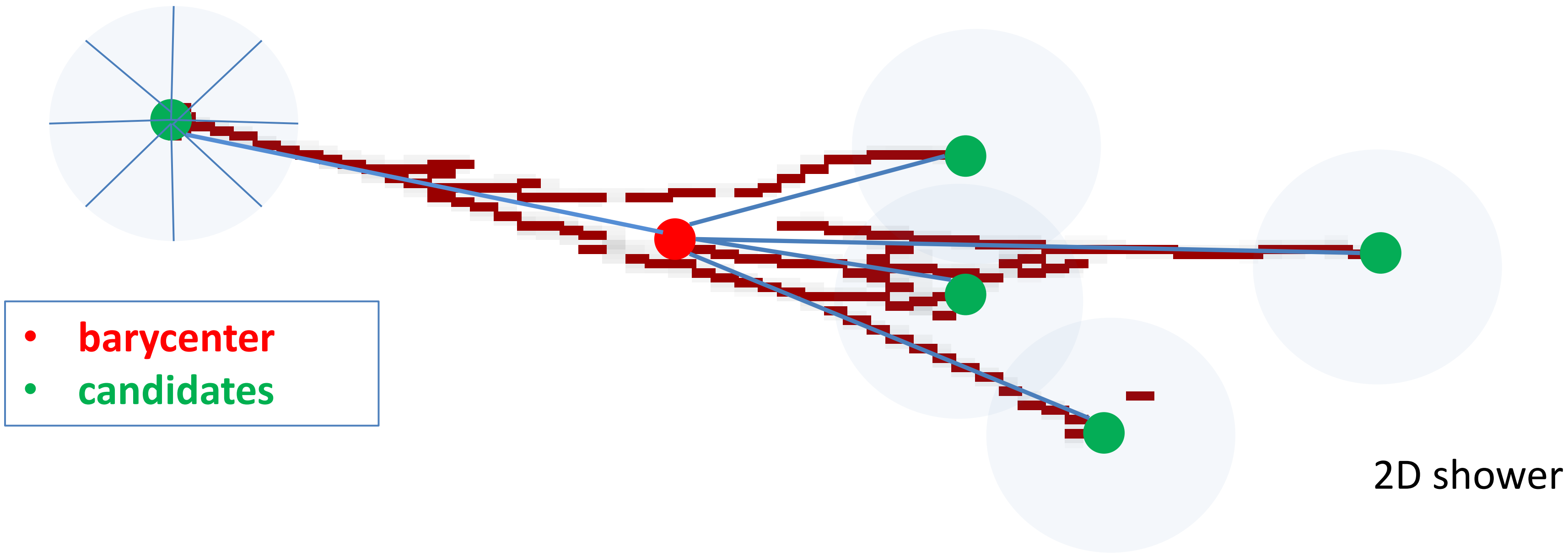
3D initial part of cascade has information about dE/dx and direction:

a) DirOfGamma alg. when shower-like cluster available,
b) 3D tracks and 3D vertices reconstructed in full event.





Isolated shower studies
reconstruction of the first part of cascade



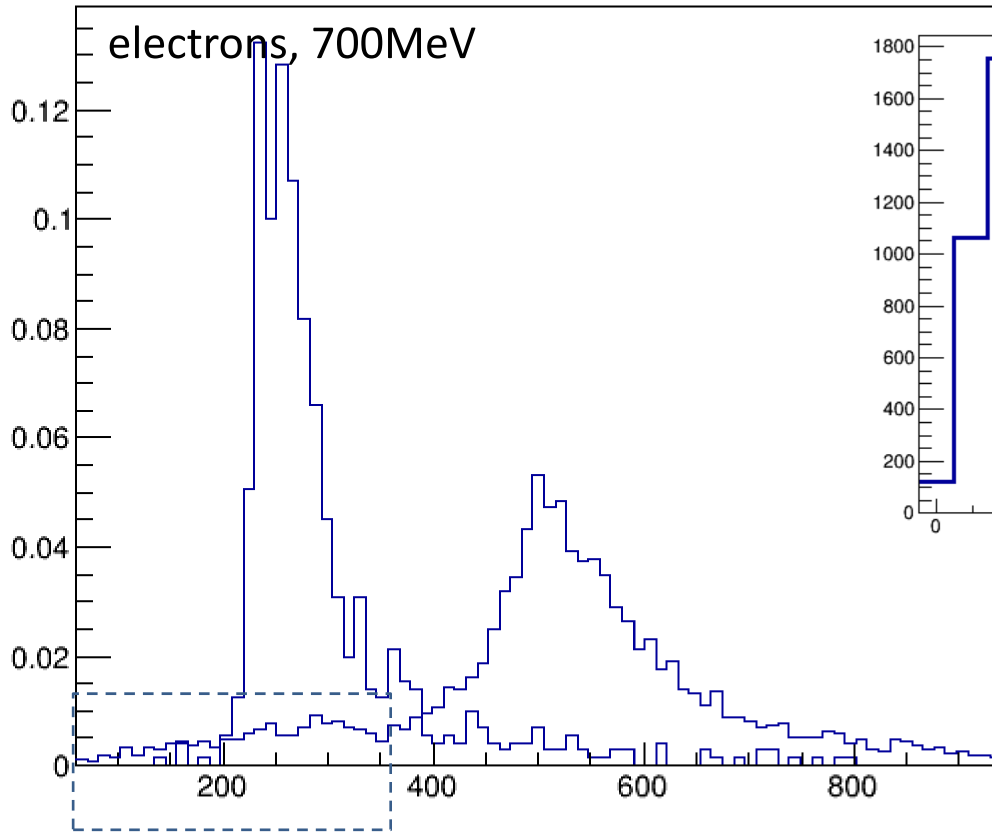
1. We consider two points as good candidates for shower start point:

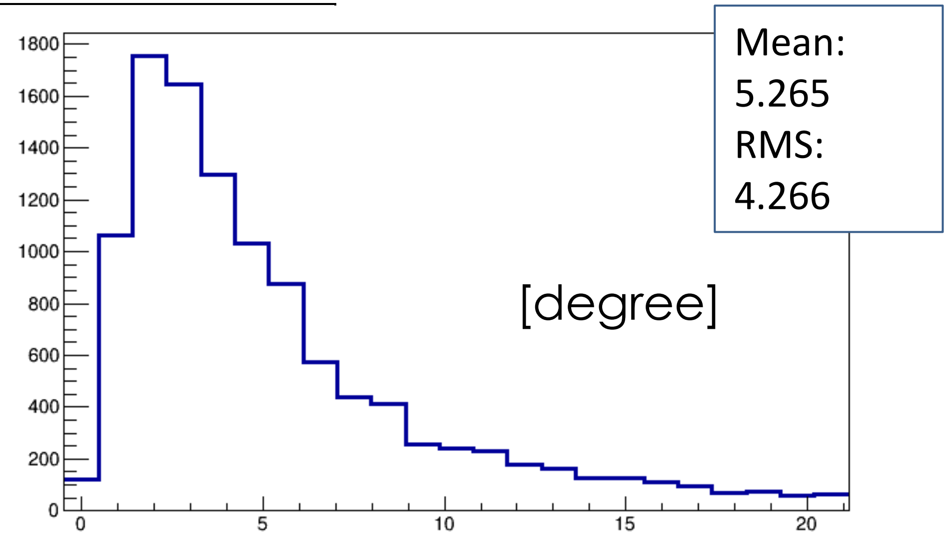
a. the most distant from the barycenter AND
b. with the highest maximum charge.
c. The candidate with the higher charge asymmetry is taken as primary vertex.

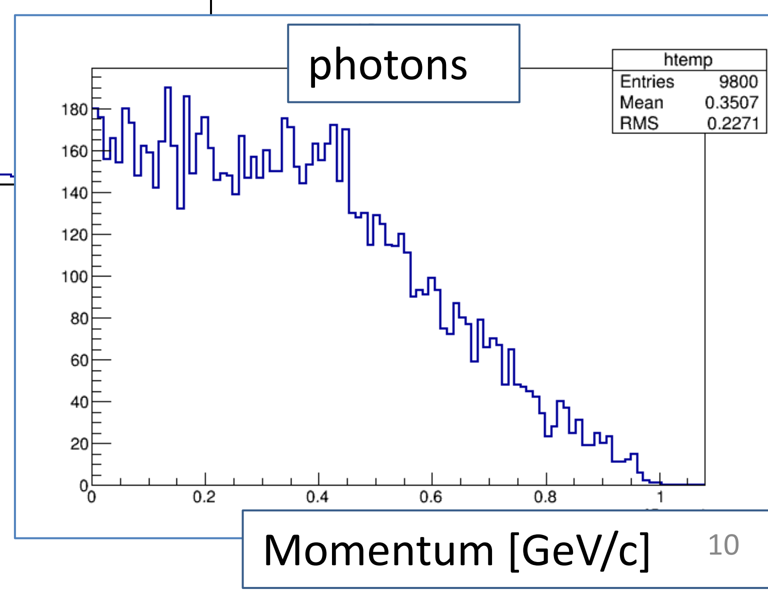
2. Corresponding starting points in different views of cascades are associated to create 3D point.

3. Build 3D segment from first hits of the shower → initial direction and dE/dx

Reconstruction of dE/dx in isolated cascade







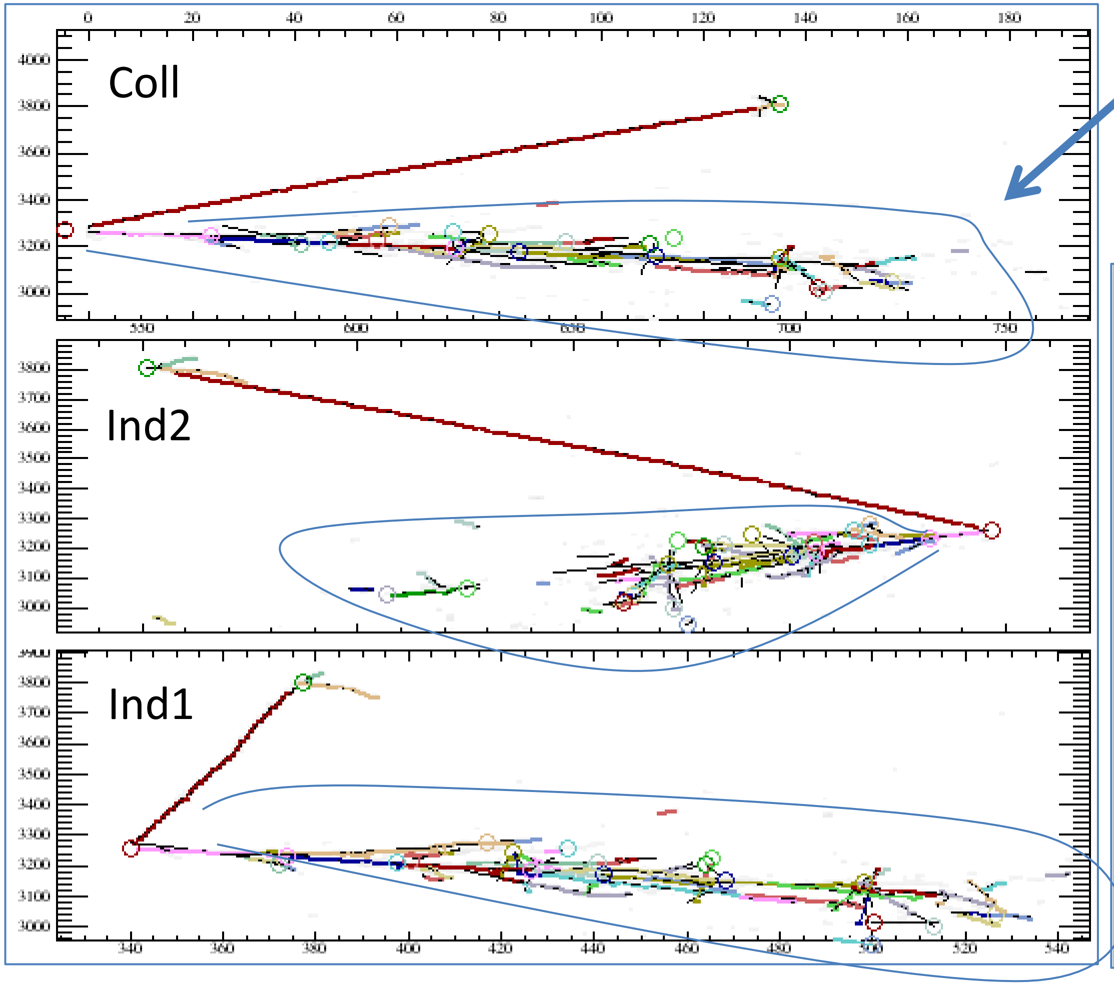
Contribution from low momentum photons: comptons and asymmetric pair production.

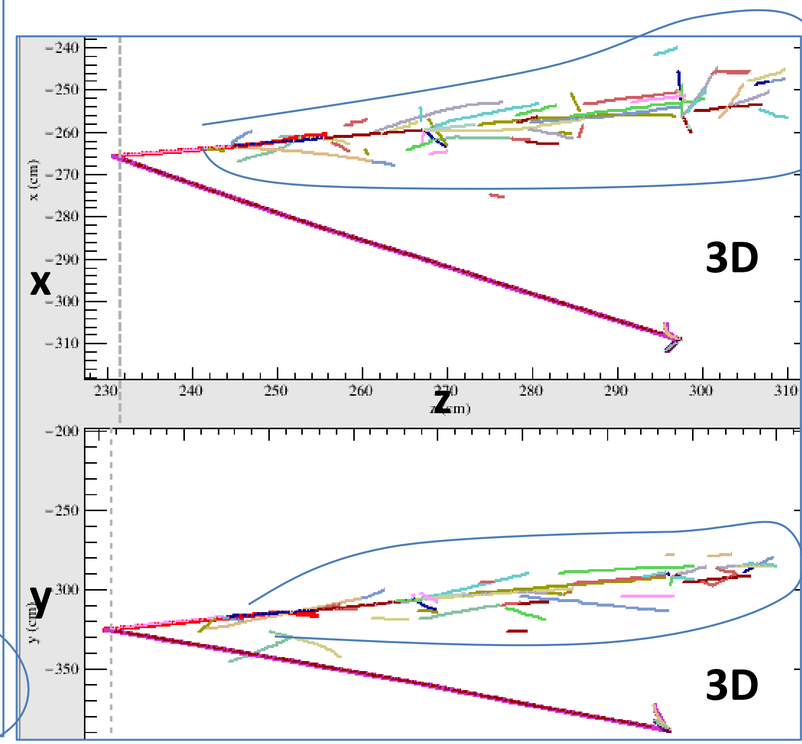
Example of reconstructed ν_e CC in far detector

shower regions:

- chaos of 3D tracks,
- chaos of vertices.

Try to resolve in 2D – work in progress





On the 3D level it is also possible to seperate dense region from tracks, can be applied if 2D does not manage.

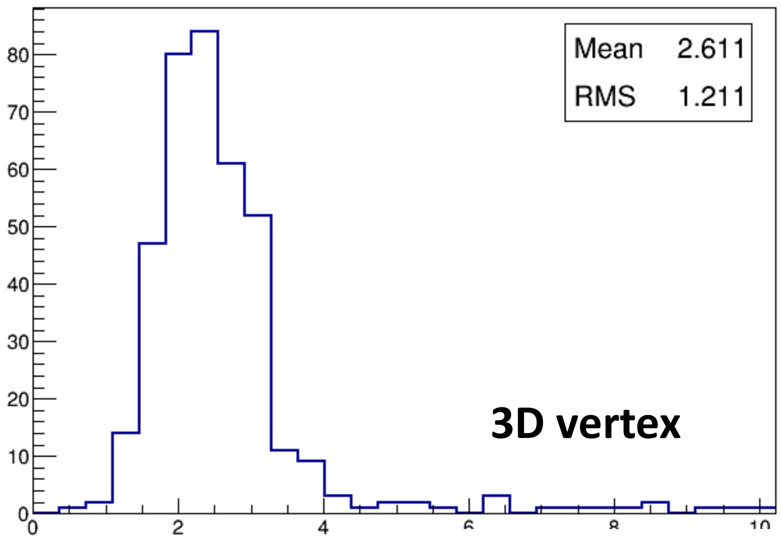
Neutrino event reconstruction as of today

- Hits
- 2D clusters
- Projection Matching Algorithm: 3D tracks, 3D vertices

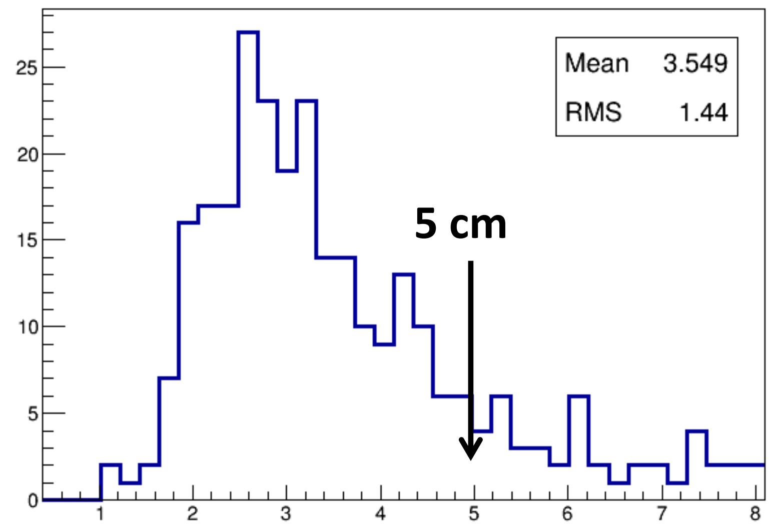
current studies include:

- Track electron efficiency
- Shower/track objects in neutrino events
- Neutrino vertex reconstruction; study surrounding of the neutrino vertex
- dE/dx of the initial part of cascades

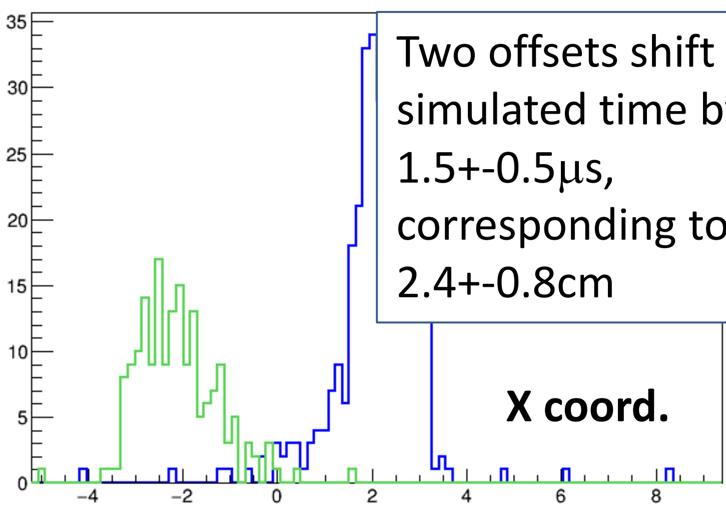
Vertex of ν_eCC



(reco – mc) [cm]



Distance of lepton from mc vtx [cm]

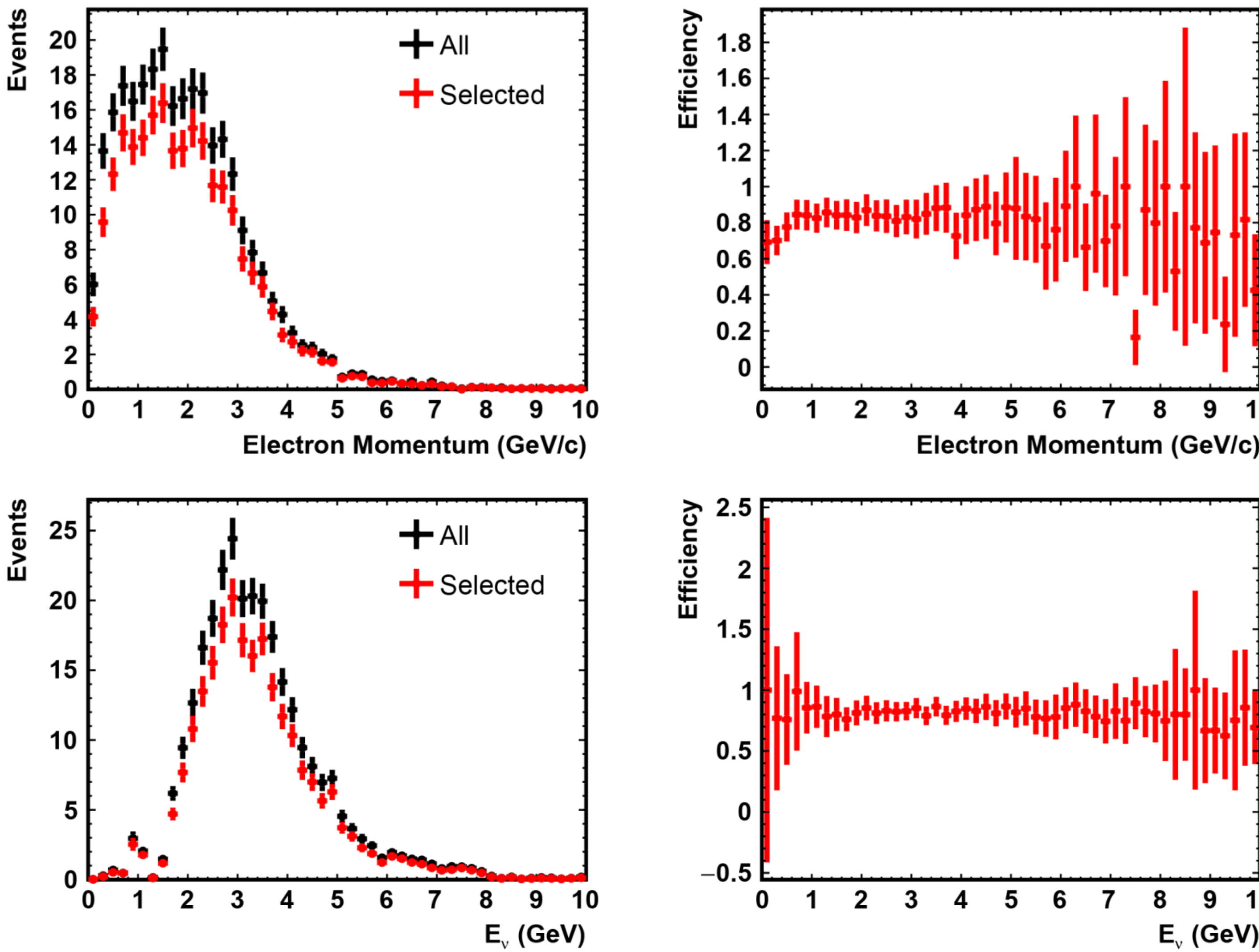


Two offsets shift the simulated time by 1.5+-0.5μs, corresponding to 2.4+-0.8cm

(reco – mc) [cm]

- Used 3D reconstructed vertices and 3D endpoints of tracks.
- Check the distance between MC vertex and the closest 3D vertex/enpoint.
- Compute the distance between mc vertex and first hit of reconstructed electron track.
- To do soon: dE/dx and check resolution without offsets in simulation.

Tracking efficiency for electrons from Tingjun



Plans

- Roughly resolve shower from track hits in 2D views, in neutrino events.
- Still improve vertex finding.

- More detailed efficiencies of reconstruction, dependencies on energy.

- If possible, skip 2D hits.

Rejection of background to ν_eCC:
- Study features of the neutrino vertex surrounding.
- dE/dx of the initial part of cascades.

- develop classifiers for ν_eCC.